



Contents lists available at SciVerse ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Look into my eyes and I will see you: Unconscious processing of human gaze

Yi-Chia Chen^a, Su-Ling Yeh^{a,b,c,*}^a Department of Psychology, National Taiwan University, Taipei, Taiwan^b Graduate Institute of Brain and Mind Sciences, National Taiwan University, Taipei, Taiwan^c Neurobiology and Cognitive Neuroscience Center, National Taiwan University, Taipei, Taiwan

ARTICLE INFO

Article history:

Received 30 January 2012

Keywords:

Face processing

Gaze direction

Head orientation

Unconscious processing

Continuous flash suppression

ABSTRACT

This study examines whether human gaze lacking the confounding factor of eye whites can be processed unconsciously and explores the critical aspects for such process. Utilizing the continuous flash suppression paradigm, a schematic face—with direct or averted gaze, and with neutral, fearful or happy expressions—was presented to one eye while dynamic masks rendered it invisible to the other eye. Schematic faces were used to avoid unwanted influence from salient eye whites. Participants' detection time of anything other than the masks was used as an index of unconscious processing time. Faster detection was found for faces with direct gaze than those with averted gaze. However, there was no difference between detection times for different facial expressions (Experiment 1) and upright-face, inverted-face, and eyes-only conditions (Experiment 2). These results confirm that, with schematic faces, gaze can be processed unconsciously regardless of facial expression, and eyes alone are sufficient for such process.

© 2012 Elsevier Inc. All rights reserved.

1. Introduction

Gaze direction is a prominent social cue. Following others' gazes to see what is happening in the vicinity is a natural tendency that exists among humans and apes (Tomonaga & Imura, 2010) and from infancy (Hoehl, Wiese, & Striano, 2008) to adulthood (Carpenter, Nagell, Tomasello, Butterworth, & Moore, 1998). Such attentional orienting by averted gaze is not limited to obvious eyes- or head-turns of the actor; it also occurs when the averted gaze is backward-masked and thus unconsciously processed (Sato, Okada, & Toichi, 2007).

A direct gaze is different from an averted gaze and has unique functions. Processing of direct gaze differs from averted gaze, as shown by a certain search asymmetry: Observers detect direct-gaze targets among averted-gaze distracters faster and more accurately than the reverse (Conty, Tijus, Hugueville, Coelho, & George, 2006; von Grunau & Anston, 1995). Further, the amplitude and latency of event-related potential (ERP) components are different for direct gaze and averted gaze (Itier, Alain, Kovacevic, & McIntosh, 2007). Unlike averted gaze that attracts viewers' attention, direct gaze reveals the interest of others toward self. Kampe, Frith, and Frith (2003) showed that hearing one's own name or seeing a face with direct gaze activates the same brain areas—the paracingulate cortex and temporal poles—involved in processing *intention*. Since the auditory processing of hearing one's own name can facilitate access to consciousness (i.e., the cocktail-party phenomenon, Moray, 1959)—direct gaze may also have a priority over averted gaze in accessing consciousness.

* Corresponding author. Address: Department of Psychology, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Taipei 10617, Taiwan.
E-mail address: suling@ntu.edu.tw (S.-L. Yeh).

Indeed, Stein, Senju, Peelen, and Sterzer (2011) found that direct gaze reached consciousness faster than averted gaze in averted head view. They used the continuous flash suppression (CFS) paradigm (Fang & He, 2005; Tsuchiya & Koch, 2005) to make face stimuli invisible. This paradigm allows prolonged suppression of a face stimulus that is presented to one eye and masked by high-contrast continuously flashed Mondrian patterns in the other eye. The release from suppression time—the time needed for a target to break the suppression and enter consciousness—was used as an index for unconscious processing time during the suppressed stage. They manipulated whether or not there was eye contact between the presented face and the participant. In the averted-gaze condition, the eyes gazed in the same direction as the averted head; in the eye-contact condition, the eyes gazed in the opposite direction, creating an impression of eye contact. A difference in the release from suppression time between the eye-contact and averted-gaze conditions indicates that gaze direction can be processed unconsciously even when the whole face is invisible.

Yang, Zald, and Blake (2007) earlier had adopted the CFS paradigm with real faces as stimuli and found that fearful faces were detected faster than neutral faces. They calculated the difference map between neutral and fearful faces, and found that the primary differences were within eye regions because of the enlarged eye whites in fearful faces, showing the critical role of salient eye whites on detection of real face under CFS suppression. As in Stein et al. (2011)'s study, it might be that the different area of eye whites between the direct and averted gaze makes them break through the suppression with different speeds.

We examined whether direct gaze can break through consciousness more easily than averted gaze when the difference in eye whites were controlled. To do so, we used gray schematic faces with black lines for eyes, nose, and mouth features (see Fig. 1) as stimuli. Specifically, the schematic faces we used contained no low-level features like eye-whites, wrinkles, etc., and thus could be used to examine whether gaze direction can still be processed unconsciously. At the same time, using schematic faces also eliminates other confounding factors like familiarity, sex, and identity. Such factors have been shown to affect the speed of conscious access of the masked critical stimuli under CFS (e.g., Jiang, Costello, Fang, Huang, & He, 2006; Jiang, Costello, & He, 2007). The same CFS paradigm with the measure of release from suppression time was used.

In addition, we manipulated facial expression (happy, neutral, and fearful) to see whether facial expression on schematic faces (without the above-mentioned confounding factors) is processed unconsciously and whether facial expression interacts with gaze processing under CFS. Previous research has found that facial expression is an important factor that interacts with gaze direction. For example, contingency of motivational orientation facilitates processing of facial expression (Adams & Franklin, 2009; Adams & Kleck, 2005). That is, direct gaze enhances emotional intensity of angry/happy faces and facilitates classification of angry faces because they are contingent in a way that they are all expressions of approach, and so too, fearful/sad faces and averted gaze are expressions of avoidance. However, it remains unknown whether interaction of gaze direction and facial expression also exists under unconscious processing. Adams and Franklin (2009) found there was reduced interaction with faster processing speed of emotional categorization, implying that the interaction between gaze and expression requires time-consuming processing. Thus, the interaction between facial expression and gaze direction may not be appropriately tested using other methods of unconscious presentation (e.g., backward masking) that only allow short-duration presentation. Since CFS allows long presentation time of the target and thus can maintain a long suppressed state, we manipulate facial expression (neutral, fearful, and happy faces) under CFS in Experiment 1 to test if the contingent motivational orientation (approach and avoidance) speeds up the detection of schematic faces.

In Experiment 2, we examine whether facial components must be integrated and processed in a configural fashion or whether only the eye region is sufficient for unconscious gaze processing. Past studies indicated that facial components (e.g., Searcy & Bartlett, 1996) are not processed individually; rather, the spatial relation between the components—i.e., configural processing—plays a critical role (for a review, see Maurer, Le Grand, & Mondloch, 2002). However, findings that supra-threshold gaze can be detected with eyes only (Conty et al., 2006; Tomonaga & Imura, 2010; von Grunau & Anston, 1995) and that the eye region contributes to faster detection of fearful faces under CFS (Yang et al., 2007) hints at the possibility that eyes alone might suffice in unconscious gaze processing.

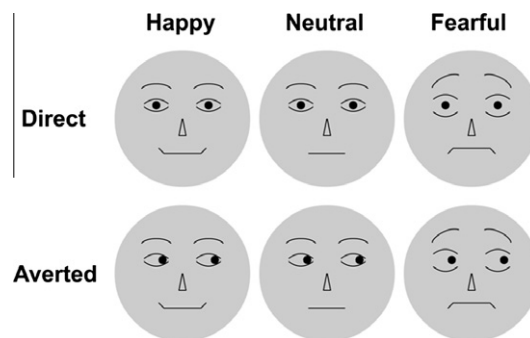


Fig. 1. Face stimuli used in the Experiment 1 were schematic faces composed of gray discs and facial components with black contours. The faces varied in facial expression and gaze direction.

2. Experiment 1

In Experiment 1, we manipulated the gaze direction (direct and averted) and facial expression (fearful, neutral, and happy) of schematic faces. Using schematic faces as stimuli, we eliminated the effect of eye whites. It is predicted that faces with direct gaze would be detected faster than those with averted gaze, and the contingency of motivational orientation should speed up the detection of faces. That is, direct gaze will facilitate the detection of happy faces (both belong to “approach” motivational orientation) and averted gaze facilitate the detection of fearful faces (“avoidance” motivational orientation), compared to neutral faces.

2.1. Materials and method

2.1.1. Participants

Thirty-one participants participated in Experiment 1 with informed consent. All participants had normal or corrected-to-normal vision and were paid or compensated by course credits. All experiments were approved by the Institutional Ethics Committee.

2.1.2. Design

Two within-subject factors were manipulated: gaze direction (direct or averted) and facial expression (happy, neutral, or fearful). Before the experiment, the three kinds of facial expressions (Fig. 1) were validated by another group of 86 participants using a 7-point scale ranging from 0 (none) to 6 (intense). Results showed each face's emotion to be correctly identified, with significantly higher values in the intended expressed emotion of schematic faces than in the alternatives ($ps < .01$), and no emotion identified for neutral faces. The face stimuli were projected to the left or right eye of each participant in a counterbalanced manner to control for ocular dominance. Each of the six conditions contained 64 repetitions, making 384 trials in total. All trials were mixed and divided into four blocks, separated with self-paced breaks.

2.1.3. Stimuli

The schematic faces were composed of gray discs (5.2° in diameter) with eyebrows ($1.1^\circ \times 0.2^\circ$), eyes ($0.8^\circ \times 0.5^\circ$), noses ($0.3^\circ \times 0.5^\circ$), and mouths (1.4°) drawn in black. Note that no eye whites were drawn to avoid the confounding from salient contrast that might be easily detected under CFS (Yang et al., 2007). Also, the curvature of the mouth that aligns with the outer-contour of the face is avoided to make the low-level features more similar between different facial expressions. Different gaze directions were created by moving the pupils to the left or right in a balanced manner. The Mondrian pattern was generated by Matlab 7.0 with randomly chosen rectangles (width and length from 0.02° to 1.07°) of different gray levels.

In the CFS paradigm, participants were presented with different images to the two eyes, with the two images counterbalanced across different eyes. The two images were placed within two squares ($14.7^\circ \times 14.7^\circ$ visual angle), each surrounded by a frame filled with random dots (0.3° in thickness); the purpose of the frames was to assist binocular fusion of the two images through a four-mirror stereoscope (Fig. 2). A schematic face on a gray background was presented within one of the squares, and dynamic Mondrian patterns changing at 10 Hz were presented within the other square. The contrast of the face gradually increased from 0% to 60% over 2 s and kept constant afterward by using Adobe After Effects CS3; thus, there was no abrupt onset to instantaneously break suppression. The stimuli presented in each trial ended with a participant's response or, if no response, after 6 s.

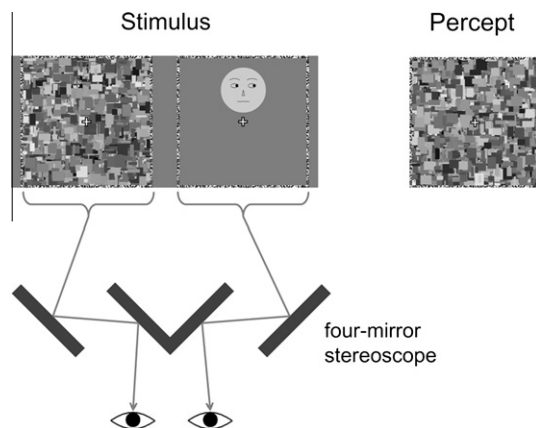


Fig. 2. Four-mirror stereoscope allowed presentation of different stimuli to each eye. In the continuous flash suppression (CFS) paradigm, one eye was presented with targets and the other with Mondrian patterns composed of overlapping rectangles. The participants' percept of the target is suppressed by the Mondrian patterns and prevented from entering consciousness for 1–2 s.

2.1.4. Apparatus

All stimuli were presented with the E-Prime 2 software (Psychological Software Tools, Pittsburgh, PA) and displayed on a ViewSonic Graphics Series G90f+ CRT monitor at a viewing distant of 57 cm. The resolution was 1024×768 , and the frame rate was 70 Hz, controlled by an ASUS BM5220/AS-D760 personal computer.

2.1.5. Procedure

Each participant sat in a dark chamber with head positioned on a chinrest. The experimenter adjusted the four-mirror stereoscope for each participant to ensure fusion of the two images.

In each trial, a fusion display was presented first. Participants were asked to reconfirm fusion of images by checking whether the two squares overlapped completely (Fig. 3) and told to inform the experimenter at any time if there was a problem regarding fusion of images. The Mondrian patterns were then presented to one eye and a gradually appearing face (above or below the fixation point) was presented to the other eye. The dichoptic presentation suppressed the face stimulus with Mondrian patterns, and the participant was unaware of the face's presence for long duration after beginning the trial (Tsuchiya & Koch, 2005). Eight practice trials that contained neutral faces with direct or averted gaze as targets preceded the experimental trials.

We adopted the “release from suppression” measure used in the CFS paradigm, following previous studies (Jiang et al., 2007; Mudrik, Breska, Lamy, & Deouell, 2011; Stein et al., 2011; Yang & Yeh, 2011; Yang et al., 2007; Zhou, Jiang, He, & Chen, 2010). When the participant started seeing anything other than the Mondrian patterns, he or she made a detection response by pressing a key as quickly as possible. The participants were told that they did not need to identify the object that appeared; they needed only to respond to any part of anything other than the Mondrian patterns. The reaction time (RT) of the detection response (i.e., the release from suppression time) was recorded. After the detection response, the participant made a location–discrimination response by answering whether the stimulus they detected had appeared at the “above” or “below” position with respect to the fixation. The accuracy was recorded to make sure that the detection response was not false alarm and the participant performed the task correctly.

The rationale of using the release from suppression time as an index of time under unconscious processing is as follows: Before the participant made the detection response, s/he was unaware of the face stimuli due to interocular suppression. Because s/he pressed the key whenever anything other than the Mondrian patterns was detected (i.e., the release from suppression time), the RTs of detection responses indicate the time needed from the suppressed (unconscious) stage to enter into conscious processing for the stimuli.

2.2. Results and discussion

The accuracy in location judgment was high ($M = 98.5\%$, $SD = 1.6\%$), which confirmed that the detection task was properly carried out. We conducted a 3 (facial expression) \times 2 (gaze direction) two-way repeated-measure analysis of variance

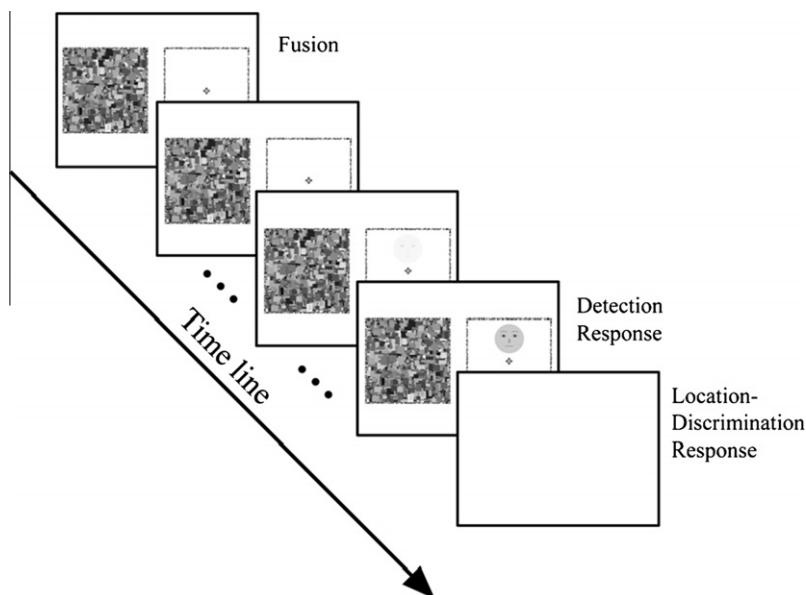


Fig. 3. After the participant confirmed the merging of the two images, the target's contrast was raised to 60% over 2 s and stayed at this contrast. The display ended when the participant made a detection response. The participant was then asked to judge the location of the target (“above” or “below” the fixation pattern).



Fig. 4. The RT differences between averted and direct gaze conditions are plotted as a function of facial expression in Experiment 1. Faces with direct gaze were detected faster than those with averted gaze, as indicated by the higher than zero RT differences across the three facial expression conditions. Although there is a trend toward a higher effect for fearful face, the main effect of facial expression and the interaction with facial expression did not reach statistical significances ($p > .05$). Error bars represent one standard error from the mean differences.

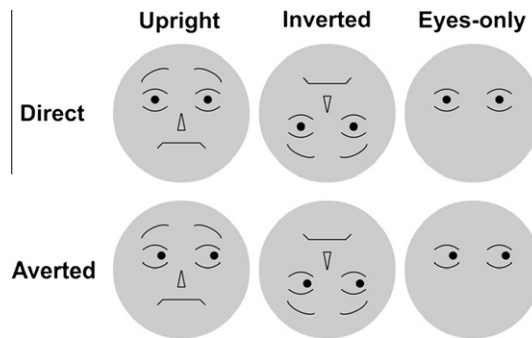


Fig. 5. Experiment 2 manipulated gaze direction and face condition (upright, inverted, and eyes-only conditions). All faces were fearful faces due to their tendency for larger gaze direction effect, as found in Experiment 1.

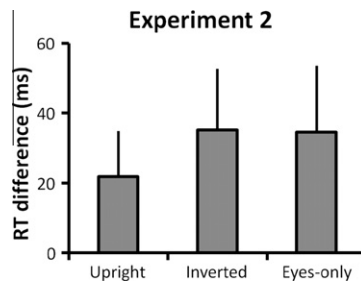


Fig. 6. The direct-gaze facilitation effect was still found in Experiment 2 with no difference among the three face conditions. Error bars represent one standard error from the mean differences.

(ANOVA) using the detection RTs of trials with correct location–discrimination responses. One participant did not respond in half the trials and, thus, those data were excluded from further analysis. A sample size of 30 was used. Only correct RTs that were within 3 standard deviations (SD) of each participant were analyzed. We found the direct-gaze facilitation effect: Detection of faces with direct gaze was faster than with averted gaze, which is supported by the main effect of gaze direction ($F(1,29) = 9.323$, $p = .005$, $\eta_p^2 = .243$). The main effect of facial expression ($F(2,58) = .237$, $p = .790$) and the interaction between expression and gaze direction ($F(2,58) = 0.711$, $p = .496$) were not significant. Paired t -tests showed no significant RT differences between the happy and neutral face conditions ($t(29) = .366$, $p = .717$) and between the fearful and neutral face conditions ($t(29) = .801$, $p = .430$). In Figs. 4 and 6, we plot the RT differences between averted and direct gaze conditions, and values significantly higher than zero indicate that faces with direct gazes are detected faster than those with averted gaze. Table 1 shows the mean RT and standard error (SE) for each of the six conditions.

The schematic face was invisible before the participant's detection response under the CFS paradigm. Nevertheless, direct gaze and averted gaze made a difference in the speed of detection. Faces with direct gaze were detected faster than those with averted gaze, indicating that gaze direction can be processed without consciousness and that direct gaze can reach

Table 1

The mean correct RT and the SE of each condition in Experiments 1 and 2.

Condition/gaze	RTs		SE	
	Direct	Averted	Direct	Averted
<i>Experiment 1</i>				
Happy	1510.26	1524.89	80.14	82.62
Neutral	1499.16	1521.39	76.12	82.33
Fearful	1497.28	1534.19	79.29	83.30
<i>Experiment 2</i>				
Upright	1358.03	1379.83	69.53	72.62
Inverted	1352.71	1387.84	66.69	74.14
Eyes-only	1349.69	1384.22	63.46	77.36

consciousness faster than averted gaze. The effect of direct gaze can be found with only slight differences in the eye region (a deviation of pupils about 0.5°) even without any eye whites being present.

We found no significant effects of facial expressions, although there was a tendency toward larger differences between the direct and averted gaze in fearful faces than in neutral and happy faces. The absence of the effect of facial expression—which emerged holistically—on gaze detection, indicates that gaze processing might not depend on holistic processing of faces but rather on specific areas such as the eye region. We tested this conjecture in Experiment 2.

3. Experiment 2

Experiment 1 showed that gaze direction of invisible schematic faces could be processed unconsciously. Was the effect caused solely by difference in parts of the faces (the location of pupils) or by the configural organization of facial components (thus allow holistic processing)? In Experiment 2, we used upright, inverted, and eyes-only conditions to investigate the effect of organization among facial components.

3.1. Materials and method

3.1.1. Participants

Twenty participants took part in Experiment 2 with informed consent. All were paid.

3.1.2. Design and stimuli

The experiment included two factors: gaze direction (direct or averted) and face condition (upright, inverted, or eyes-only faces). The stimuli used in Experiment 2 were fearful faces due to their tendency for larger gaze direction effect. In the inverted condition, faces were simply inverted. Eyes-only stimuli were created by removing other facial components of upright faces (Fig. 5). All other settings were the same as in Experiment 1.

3.2. Results and discussion

The accuracy in the location judgment was high ($M = 98.7\%$, $SD = 1.1\%$). A 3 (face condition) \times 2 (gaze direction) two-way ANOVA shows that detection of faces with direct gaze was faster than those with averted gaze, which is supported by the main effect of gaze direction ($F(1, 19) = 7.928$, $p = .011$, $\eta_p^2 = .294$). The main effect of face condition ($F(2, 38) = 0.055$, $p = .946$) and the interaction between gaze direction and face condition ($F(2, 38) = 0.235$, $p = .791$) were not significant. The direct-gaze facilitation effect was evident in the upright, inverted, and eyes-only condition (Fig. 6 and Table 1). This suggests that the detection facilitation of direct gaze does not need the configural organization of the facial components; eyes alone are sufficient.

4. General discussion

Using schematic faces, which avoid the possible confounding factors like familiarity, sex, identity, and salient eye whites that arise from real faces, we examined whether gaze direction can be processed unconsciously under CFS, whether facial expression interacts with it, and whether configural processing of the whole face is necessary for unconscious gaze detection. Results from two experiments showed that direct gaze facilitates detection of schematic faces rendered invisible due to interocular suppression by continuous flashing masks. That is, direct gaze is given the priority of conscious access compared to averted gaze even without salient eye whites, suggesting that implicit gaze processing is not only emergent from low-level features. The interaction between facial expression and gaze direction was not found in Experiment 1. Configural processing is not necessary to produce this direct-gaze facilitation effect because the eyes-only condition in Experiment 2 produced similar effects in both the upright and inverted whole face conditions.

Our use of schematic faces without eye whites removed the effects of local salient contrast of the eyes, and minimized low-level differences between direct gaze and averted gaze. Faster detection of faces with direct gaze rather than averted gaze was still found regardless of facial expression in Experiment 1, indicating the robustness of efficient processing of direct gaze. This is consistent with Stein et al. (2011)'s study using real faces in averted head view. Taken together the results of our Experiment 1 and those of Stein et al. (2011), the direct-gaze facilitation effect can be found with both real and schematic faces, as well as direct and averted head views, indicating that it is the abstract meaning such as the social information of gaze direction—rather than low-level features like eye whites—that causes the effect.

Experiment 2 further showed that gaze direction can be processed without other facial components at the suppressed stage (i.e., eyes alone are sufficient), indicating that the effect of gaze direction does not result from configural face processing. Then where does the effect come from? One possibility is that the eyes are not processed configurally with other facial components, neither are they degraded to simply low-level black and gray patches, but remain processed as a complete component that conveys unique information, like *intention*. This account is consistent with previous findings (Collishaw & Hole, 2000; Freire, Lee, & Symons, 2000; Le Grand, Mondloch, Maurer, & Brent, 2001) showing that component processing of faces is not affected by inversion of the faces. Other researchers also reported convergent findings. Yang et al. (2007) used the CFS paradigm to investigate the processing of fearful faces and inferred that emotional information was extracted mainly from the eye region (see also Conty et al., 2006; Sato et al., 2007; Tomonaga & Imura, 2010; von Grunau & Anston, 1995). The possible reason for the facilitation of direct gaze on detection might be the effectiveness of eye-region processing. Mondloch, Le Grand, and Maurer (2002) showed that component processing—face processing that does not need the configural organization of facial components—occurs earlier in development than configural processing. This might indicate that component processing of faces is simpler than configural processing and, thus, more effective.

We did not find faster detection of fearful faces as Yang et al. (2007) did, probably because they used real faces instead of schematic faces as we used here. Removing the salient eye whites in our schematic faces eliminated the effect, showing that eye whites might be essential in the unconscious processing of fearful real faces. We did not find detection facilitation of happy faces as Mack and Rock (1998)'s study might imply either. Using schematic faces, Mack and Rock (1998) found that happy faces were immune from inattentional blindness while neutral and inverted faces were not. The difference in the paradigms used in Mack and Rock (1998) and here may have caused the discrepancy in results. In their study, the inattentional blindness paradigm was used wherein the participant compared the line length of a large cross and a schematic face was shown in one of the quadrant segregated by the cross in the supposedly unattended background. Note that the faces were clearly visible if it was attended to. Another difference is in the mouth of the schematic faces. Mack and Rock used faces with an outer-contour and a curvature representing the mouth and found that such stimuli resisted inattentional blindness as did happy faces. Removing the curvature eliminated the effect. Their results suggest the important role of the curvature mouth, which is lacking in our stimuli in which the mouth is a composite of three straight lines. This also raises an interesting issue that it is possible for the curvature of the happy faces to be the essential feature that makes the faces break through suppression and enter consciousness under CFS. Also, we did not find the interaction between facial expression and gaze direction as shown in previous studies (Adams & Franklin, 2009; Adams & Kleck, 2005). These researchers, however, used visible stimuli and explicit measures like emotional rating and categorization. It is possible that the motivational orientation (i.e., approach or avoidance) of gaze and expression might not be interactively processed under CFS when the stimuli are completely invisible—if such interaction requires time-consuming processing (Adams & Franklin, 2009).

The lack of evidence of configural processing in Experiment 2 also explains the absence of the effect of facial expression in Experiment 1, and this is consistent with previous findings that facial expression emerges holistically (e.g., Kaiser, Le Grand, & Tanaka, 2006). If the holistic processing of faces is abolished or reduced under CFS as shown in Experiment 2, and some essential low-level features like salient eye whites, curvature of the mouth, etc., eliminated as in our study, facial expression might not be processed with our stimuli (cf. Mack & Rock, 1998; Yang et al., 2007). Taken together with the findings in our Experiment 1 and 2, we suggest that CFS allows the component processing of the eyes which produces the direct-gaze facilitation effect, and the holistic processing of the whole face is attenuated (due to abolishment of configural organization) thus facial expression has no effect on the release from suppression time.

As shown in the current study, gaze direction is processed unconsciously with eyes-only schematic faces, indicating the effectiveness of gaze processing. Such effectiveness might be adaptive, arising naturally in the evolution process, because of the functions of gazes. Direct gaze predicts others' direction of attack or helping behaviors. It indicates others' subsequent approaching behavior, as shown by Kampe et al. (2003), who demonstrated that direct gaze has an effect in the activation of the neural system similar to hearing one's own name. The faster detection of faces with direct gaze than faces with averted gaze is adaptive because it is important to evaluate immediately whether a direct gaze is a friendly look or indicates an attack. As a result, direct gaze can be processed effectively and unconsciously, without bringing the stimuli to the conscious level. On the other hand, averted gaze reveals the attended direction of others, as in the social phenomenon of joint-attention (Carpenter et al., 1998) in which a person follows another person's gaze and attends to the same thing. People with pervasive developmental disorders—including autism and Asperger's Disorder, which confuse social signals and lack joint attention ability—also show deficits in gaze processing (Dawson et al., 2004; Sato, Uono, Okada, & Toichi, 2010). Evidence supporting the idea that unconscious gaze processing has evolutionary roots includes the fact that infants detect gaze early in life (2-to-5-day-old newborns in Farroni, Massaccesi, Pividori, & Johnson, 2004; 2-to-4-month-olds in Scaife & Bruner, 1975) and that even chimpanzees are more sensitive to direct gaze than averted gaze (Tomonaga & Imura, 2010).

The direct-gaze facilitation effect may come from the differences in visual processing between direct gaze and averted gaze. This indication is consistent with previous studies using visual search and ERP recordings (Conty et al., 2006; Itier et al., 2007; Tomonaga & Imura, 2010; von Grunau & Anston, 1995). As mentioned, processing of direct gaze involves specific intentional decoding of self-directed information, possibly activating paracingulate cortex and temporal poles (Kampe et al., 2003). On the other hand, processing of averted gaze elicits the attentional orienting mechanism that functions to guide gaze-following behaviors to conjunct with others' attentional focus, which may correlate with the activation of superior temporal sulcus (Kingstone, Tipper, Ristic, & Ngan, 2004). Unlike the current study, which clearly demonstrates unconscious gaze processing, the aforementioned studies did not differentiate the explicit processing that requires consciousness from unconscious processing. Further studies are needed to see, under the unconscious state, whether direct gaze and averted gaze are processed through different brain areas that are responsible for self-directed information and gaze following—and, thereby, different mechanisms—or share the same underlying mechanism but simply with different efficiency.

Acknowledgments

This research is supported by Grants NSC 99-2815-C-002-108-H and NSC 98-2410-H-002-023-MY3 from National Science Council of Taiwan. We thank Arthur Woodward and our lab members—Hsin-I Liao, Yung-Hao Yang, Kuan-Ming Chen, San-Yuan Lin, Cheng-An Lee, Shuo-Heng Li, Ya-Yeh Tsai, Pao-Chou Cho, and Ren-Jie Wang—for their useful comments. Special thanks go to Yung-Hao Yang for assisting in set-up of the programs and stimuli.

References

- Adams, R. B., & Franklin, R. G. (2009). Influence of emotional expression on the processing of gaze direction. *Motivation and Emotion*, 33(2), 106–112.
- Adams, R. B., & Kleck, R. E. (2005). Effects of direct and averted gaze on the perception of facially communicated emotion. *Emotion*, 5(1), 3–11.
- Carpenter, M., Nagell, K., Tomasello, M., Butterworth, G., & Moore, C. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the Society for Research in Child Development*, 63(4), i-174.
- Collishaw, S. M., & Hole, G. J. (2000). Featural and configurational processes in the recognition of faces of different familiarity. *Perception*, 29(8), 893–909.
- Conty, L., Tijus, C., Hugueville, L., Coelho, E., & George, N. (2006). Searching for asymmetries in the detection of gaze contact versus averted gaze under different head views: A behavioural study. *Spatial Vision*, 19(6), 529–545.
- Dawson, G., Toth, K., Abbott, R., Osterling, J., Munson, J., Estes, A., et al (2004). Early social attention impairments in autism: Social orienting, joint attention, and attention to distress. *Developmental Psychology*, 40(2), 271–283.
- Fang, F., & He, S. (2005). Cortical responses to invisible objects in the human dorsal and ventral pathways. *Nature Neuroscience*, 8(10), 1380–1385.
- Farroni, T., Massaccesi, S., Pividori, D., & Johnson, M. (2004). Gaze following in newborns. *Infancy*, 5(1), 39–60.
- Freire, A., Lee, K., & Symons, L. A. (2000). The face-inversion effect as a deficit in the encoding of configural information: Direct evidence. *Perception*, 29(2), 159–170.
- Hoehli, S., Wiese, L., & Striano, T. (2008). Young infants' neural processing of objects is affected by eye gaze direction and emotional expression. *PLoS ONE*, 3(6), e23889.
- Itier, R. J., Alain, C., Kovacevic, N., & McIntosh, A. R. (2007). Explicit versus implicit gaze processing assessed by ERPs. *Brain Research*, 1177, 79–89.
- Jiang, Y., Costello, P., Fang, F., Huang, M., & He, S. (2006). Gender and sexual orientation dependent attentional effect of invisible images. *Proceedings of the National Academy of Sciences*, 103(45), 17048–17052.
- Jiang, Y., Costello, P., & He, S. (2007). Processing of invisible stimuli: Faster for upright faces and recognizable words to overcome interocular suppression. *Psychological Science*, 18(4), 349–355.
- Kaiser, M. D., Le Grand, R., & Tanaka, J. W. (2006). On holistic processing of facial expressions. *Journal of Vision*, 6(6), 685.
- Kampe, K. K. W., Frith, C. D., & Frith, U. (2003). "Hey John": Signals conveying communicative intention toward the self activate brain regions associated with "mentalizing", regardless of modality. *The Journal of Neuroscience*, 23(12), 5258–5263.
- Kingstone, A., Tipper, C., Ristic, J., & Ngan, E. (2004). The eyes have it!: An fMRI investigation. *Brain and Cognition*, 55(2), 269–271.
- Le Grand, R., Mondloch, C. J., Maurer, D., & Brent, H. P. (2001). Neuroperception: Early visual experience and face processing. *Nature*, 410(6831), 890.
- Mack, A., & Rock, I. (1998). *Inattention blindness*. Cambridge, MA: The MIT Press.
- Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences*, 6(6), 255–260.
- Mondloch, C. J., Le Grand, R., & Maurer, D. (2002). Configural face processing develops more slowly than featural face processing. *Perception*, 31(5), 553–566.
- Moray, N. (1959). Attention in dichotic listening: Affective cues and the influence of instructions. *Quarterly Journal of Experimental Psychology*, 11(1), 56–60.
- Mudrik, L., Breska, A., Lamy, D., & Deouell, L. Y. (2011). Integration without awareness. *Psychological Science*, 22(6), 764–770.
- Sato, W., Okada, T., & Toichi, M. (2007). Attentional shift by gaze is triggered without awareness. *Experimental Brain Research*, 183(1), 87–94.
- Sato, W., Uono, S., Okada, T., & Toichi, M. (2010). Impairment of unconscious, but not conscious, gaze-triggered attention orienting in Asperger's Disorder. *Research in Autism Spectrum Disorders*, 4(4), 782–786.
- Scaife, M., & Bruner, J. S. (1975). The capacity for joint visual attention in the infant. *Nature*, 253(5489), 265–266.
- Searcy, J. H., & Bartlett, J. C. (1996). Inversion and processing of component and spatial-relational information in faces. *Journal of Experimental Psychology: Human Perception and Performance*, 22(4), 904–915.
- Stein, T., Senju, A., Peelen, M. V., & Sterzer, P. (2011). Eye contact facilitates awareness of faces during interocular suppression. *Cognition*, 119(2), 307–311.
- Tomonaga, M., & Imura, T. (2010). Visual search for human gaze direction by a chimpanzee (*Pan troglodytes*). *PLoS ONE*, 5(2), e9131.
- Tsuchiya, N., & Koch, C. (2005). Continuous flash suppression reduces negative afterimages. *Nature Neuroscience*, 8(8), 1096–1101.
- von Grunau, M., & Anston, C. (1995). The detection of gaze direction: A stare-in-the-crowd effect. *Perception*, 24(11), 1297–1313.
- Yang, Y. H., & Yeh, S. L. (2011). Accessing the meaning of invisible words. *Consciousness and Cognition*, 20(2), 223–233.
- Yang, E., Zald, D. H., & Blake, R. (2007). Fearful expressions gain preferential access to awareness during continuous flash suppression. *Emotion*, 7(4), 882–886.
- Zhou, W., Jiang, Y., He, S., & Chen, D. (2010). Olfaction modulates visual perception in binocular rivalry. *Current Biology*, 20(15), 1356–1358.